Hazard Profile – Severe Storm

Summary

- The hazard – For the purposes of this assessment, a Severe Storm is defined as an atmospheric disturbance featuring sustained strong winds (40+ MPH) and/or significant precipitation (rain or snow). Such events typically occur during the winter months and generally move into the State from the Pacific Ocean.

- Previous occurrences – According to the National Weather Service, events meeting the Severe Storm definition have produced some of the most significant weather events in the 20th Century in Washington State, including snowstorms in January 1916 and January 1950; the Columbus Day Windstorm in October, 1962 (still the most dramatic weather ever to hit the State); the Inauguration Day Windstorm in January, 1993; the January 1997 Winter Storm; and, most recently, the December 2006 Hanukkah Eve Windstorm and the December 2007 windstorm and flood, the December 2008 snow storms, and the January 2009 floods.

- Probability of future events - Because of its location on the windward coast of the North Pacific Ocean and its mountainous topography which influences precipitation patterns, Washington State is assured of powerful Severe Storm events in the future.

- Jurisdictions at greatest risk – While Severe Storms have impacted every corner of the State, counties most at risk include those along the Pacific Coast, counties within the Puget Sound basin, counties along the east slopes of the Cascade Mountains, and some counties in SE Washington as well as Spokane County.

- Special note – This profile will not attempt to estimate potential losses to state facilities due to severe storm. The state does not have data on which to base a determination of which facilities might be most vulnerable to either high winds or winter storm.

Introduction [1]

All areas of Washington State are vulnerable to severe weather. A severe storm is an atmospheric disturbance that results in one or more of the following phenomena: strong winds, thunderstorms with large hail and tornados, rain, snow, or other mixed precipitation. Typically, a severe storm can cause major impacts to transportation, infrastructure and services, and loss of utilities. Most storms move into Washington from the Pacific Ocean.

The following severe storm elements are considered for this profile (using National Weather Service definitions):

- High winds – Storms with sustained winds of 40 mph or gusts of 58 mph or greater, not caused by thunderstorms, expected to last for an hour or more.

- Winter storm – A storm with significant snowfall, ice, and/or freezing rain; the quantity of precipitation varies by elevation. Heavy snowfall is 4 inches or more in a 12-hour period, or 6 or more inches in a 24-hour period in non-mountainous areas; and 12 inches or more in a 12-hour period or 18 inches or more in a 24-hour period in mountainous areas.

Note: Although flooding is a result of severe rainstorms, see Tab 5 "Flood" for a separate profile on the flood hazard.

Washington's Climate[2]

The location of the State of Washington on the windward coast in mid-latitudes is such that climatic elements combine to produce a predominantly marine-type climate west of the Cascade Mountains, while east of the Cascades, the climate possesses both continental and marine characteristics.

The state's climate is impacted by two significant factors:

- Mountain ranges. The Olympic Mountains and the Cascade Mountains affect rainfall. The first major release of rain occurs along the west slopes of the Olympics, and the second is along the west slopes of the Cascade Range. Additionally, the Cascades are a topographic and climatic barrier. Air warms and dries as it descends along the eastern slopes of the Cascades, resulting in near desert conditions in the lowest section of the Columbia Basin in eastern Washington. Another lifting of the air occurs as it flows eastward from the lowest elevations of the Columbia Basin toward the Rocky Mountains. This results in a gradual increase in precipitation in the higher elevations along the northern and eastern borders of the state.

- Location and intensity of semi-permanent high and low-pressure areas over the North Pacific Ocean. During the summer and fall, circulation of air around a high-pressure area over the North Pacific brings a prevailing westerly and northwesterly flow of comparatively dry, cool and stable air into the Pacific Northwest. As the air moves inland, it becomes warmer and drier, resulting in a dry season. In the winter and spring, the high pressure resides further south while low pressure prevails in the Northeast Pacific. Circulation of air around both pressure centers brings a prevailing southwesterly and westerly flow of mild, moist air into the Pacific Northwest. Condensation occurs as the air moves inland over the cooler land and rises along the windward slopes of the mountains. This results in a wet season beginning in late October or November, reaching a peak in winter, gradually decreasing by late spring.

West of the Cascade Mountains, summers are cool and relatively dry while winters are mild, wet and generally cloudy.

In interior valleys, measurable rainfall occurs on 150 days each year and on 190 days in the mountains and along the coast. Thunderstorms over the lower elevations occur up to 10 days each year and over the mountains up to 15 days. Damaging hailstorms rarely occur in most localities of western Washington. During July and August, the driest months, two to four weeks can pass with only a few showers; however, in December and January, the wettest months, precipitation is frequently recorded on 20 to 25 days or more each month. The range in annual precipitation is from about 20 inches in an area northeast of the Olympic Mountains to 150 inches along the southwestern slopes of these mountains. Snowfall is light in the lower elevations and heavy in the mountains.

During the wet season, rainfall is usually of light to moderate intensity and continuous over a period of time, rather than heavy downpours for brief periods; heavier intensities occur along the windward slopes of the mountains.

The strongest winds are generally from the south or southwest and occur during the fall and winter. In interior valleys, sustained wind velocities usually reach 40 to 50 mph each winter, and 75 to 90 mph a few times every 50 years. The highest summer and lowest winter temperatures generally occur during periods of offshore easterly winds.

The climate east of the Cascade Mountains has characteristics of both continental and marine climates. Summers are warmer, winters are colder, and precipitation is less than in western Washington. Extremes in both summer and winter temperatures generally occur when air from the continent influences the inland basin.

In the driest areas, rainfall occurs about 70 days each year in the lowland and about 120 days in the higher elevations near the eastern border and along the eastern slopes of the Cascades. Annual precipitation ranges from seven to nine inches near the confluence of the Snake and Columbia Rivers in the Tri-Cities area, 15 to 30 inches along the eastern border and 75 to 90 inches near the summit of the Cascade Mountains. During July and August, four to eight weeks can pass with only a few scattered showers. Thunderstorms, most as isolated cells, occur on one to three days each month from April through September. A few damaging hailstorms are reported each summer.

During the coldest months, freezing drizzle occasionally occurs, as does a Chinook wind that produces a rapid rise in temperature.

During most of the year, the prevailing wind is from the southwest or west. The frequency of northeasterly winds is greatest in the fall and winter. Sustained wind velocities ranging from four to 12 mph can be expected 60 to 70 percent of the time; 13 to 24 mph, 15 to 24 percent of the time; and 25 mph or higher, 1 to 2 percent of the time. The highest wind velocities are from the southwest or west and are frequently

associated with rapidly moving weather systems. Extreme sustained wind velocities can be expected to reach 50 mph at least once in two years; 60 to 70 mph once in 50 years; and 80 mph once in 100 years.

Hazardous Weather Seasons[3]

Primary flood season
- Western Washington – November through February.
- Eastern Washington (east slopes of Cascades) – May and June.

Windstorm season – October through March.

Snow season:
- Western Washington – mid November through mid March.
- Eastern Washington – November through March.
- Mountains – mid October through May.

Significant Severe Storms in Washington State – 1900 to Present

> *Note: Severe storms that resulted in flooding are described in more detail in the Flood hazard profile.*

January/February 1916 – Seattle's Greatest Snowstorm[4]

One of the top 10 weather events in Washington during the 20th Century, according to the National Weather Service, Seattle Forecast Office.

Seattle's snowfall in January was 23 inches, and February snowfall was 35 inches, for a two-month total of 58 inches.

Seattle recorded its maximum snowfall ever in a 24-hour period, with 21.5 inches on February 1. Other parts of western Washington received between two to four feet of snow. Winds created snowdrifts as high as five feet.

The region was crippled, with transportation essentially halted.

May/June 1948 – Greatest Spring Snowmelt Flooding[5]

One of the top 10 weather events in Washington during the 20th Century, according to the National Weather Service, Seattle Forecast Office.

Snowmelt flooding broke lake and river records in Eastern Washington and along the Columbia River to the Pacific Ocean. Flood lasted 45 days.

Vancouver, Camas, Kalama, and Longview suffered flood damage.

January 13, 1950 – The January 1950 Blizzard[6]

One of the top 10 weather events in Washington during the 20th Century, according to the National Weather Service, Seattle Forecast Office.

On this date, 21.4 inches of snow fell in Seattle, the second greatest 24-hour snowfall recorded. The snowfall was accompanied by 25-40 mph winds. The storm claimed 13 lives in the Puget Sound area.

January had 18 days with high temperatures of 32 degrees or lower. The winter of 1949-50 was the coldest winter on record in Seattle, with an average temperature of 34.4 degrees.

Eastern Washington, North Idaho, and parts of Oregon also were paralyzed by the snow – some lower-elevation snow depths reached nearly 50 inches and temperatures plunged into minus teens and twenties. Several dozen fatalities occurred.

October 12, 1962 – The Columbus Day Wind Storm[7, 8]

The top weather event in Washington during the 20th Century, according to the National Weather Service, Seattle Forecast Office.

This storm is the greatest windstorm to hit the Northwest since weather recordkeeping began in the 19th century, and called the "mother of all wind storms" in the 1900s. All windstorms in the Northwest are compared to this one.

The Columbus Day Storm was the strongest widespread non-tropical windstorm to strike the continental U.S. during the 20th century, affecting an area from northern California to British Columbia.

The storm claimed seven lives in Washington State; 46 died throughout the impacted region. One million homes lost power. More than 50,000 homes were damaged. Total property damage in the region was estimated at $235 million (1962 dollars). The storm blew down 15 billion board feet of timber worth $750 million (1962 dollars); this is more than three times the timber blown down by the May 1980 eruption of Mount St. Helens, and enough wood to replace every home in the state.

Highest recorded wind speeds (before power went out at recording stations):

- Naselle, Washington Coast – gust to 160 mph.
- Bellingham and Vancouver – gusts of 113 mph.
- Renton – gust of 100 mph.
- Tacoma – gust of 88 mph.

April 5, 1972 – Washington's Deadliest Tornado Outbreak[9, 10]

One of the top 10 weather events in Washington during the 20th Century, according to the National Weather Service, Seattle Forecast Office.

Three tornadoes touched down in Washington State on this day:

- An F3 tornado touched down in Vancouver; it swept through a grocery store, bowling alley, and grade school near where Vancouver Mall is today. It caused six deaths, 300 injuries, and $50 million in damage.
- Later that day, another F3 tornado touched down west of Spokane near Davenport, and an F2 tornado struck rural Stevens County.
- Numerous severe thunderstorms with large hail and damaging winds were reported over other areas of eastern Washington.

An F3 tornado (prior to 2008) has winds of 158-206 mph, and is capable of severe damage. An F2 tornado has winds of 113-157 mph and is capable of considerable damage.

Because of these tornados, Washington led the nation in tornado deaths in 1972.

December 1982 [11]

Federal Disaster #676. Disaster assistance provided – $1.7 million. Small Business Administration loaned $1 million to home and business owners for damages.

Severe storm and coastal flooding affected Whatcom County. Four persons injured, 122 people evacuated; 129 homes and 113 businesses damaged; $1.7 million in public facility damage.

November 1990 – Statewide Flooding[12, 13]

Federal Disaster #883. Stafford Act disaster assistance provided – $57 million.

One of the top 10 weather events in Washington during the 20th Century, according to the National Weather Service, Seattle Forecast Office.

Widespread, major flooding on western Washington rivers and several eastern Washington rivers.

This storm caused two deaths. Damage estimated at $250 million. The Interstate 90 – Lake Washington floating bridge between Seattle and Mercer Island sank during this storm event.

December 1990 – Severe Storm

Federal Disaster #896. Stafford Act disaster assistance provided – $5.1 million.

Floods, snow, and high winds affected the counties of Island, Jefferson, King, Kitsap, Lewis, Pierce, San Juan, Skagit, Snohomish, and Whatcom.

January 20, 1993 – The Inauguration Day Wind Storm[14, 15]

Federal Disaster #981. Stafford Act disaster assistance provided – $24.2 million.

Hurricane force winds swept King, Lewis, Mason, Pierce, Snohomish, Thurston and Wahkiakum counties.

This storm claimed five lives. More than 870,000 homes and businesses lost power. Fifty-two single-family homes, mobile homes, and apartment units were destroyed, and 249 incurred major damage, many from falling trees and limbs. More than 580 businesses were damaged. Total damage in western Washington estimated at $130 million.

Winds in Puget Sound area gusted to 70 mph. A gust at Cape Disappointment on the Washington Coast reached 98 mph.

February 1996 – Storm with Widespread Flooding, Snowmelt, Mudslides in Washington, Oregon, and Idaho[16, 17]

Federal Disaster #1100. Stafford Act disaster assistance provided – $113 million. Small Business Administration disaster loans approved - $61.2 million.

One of the top 10 weather events in Washington during the 20th Century, according to the National Weather Service, Seattle Forecast Office.

Heavy rainfall, mild temperatures and snowmelt caused flooding and mudslides in Adams, Asotin, Benton, Clark, Columbia, Cowlitz, Garfield, Grays Harbor, King, Kitsap, Kittitas, Klickitat, Lewis, Lincoln, Pierce, Skagit, Skamania, Snohomish, Spokane, Thurston, Wahkiakum, Walla Walla, Whitman and Yakima counties, and the Yakama Indian Reservation.

This storm caused major flooding on rivers of western and southeast Washington. (See Flood hazard profile, Tab 5.1.4, pages 8-9, for more.)

Mudslides occurred throughout the state.

Three deaths, 10 people injured. Nearly 8,000 homes damaged or destroyed. Traffic flow both east and west, and north and south along major highways was shut down for several days. An avalanche closed Interstate 90 at Snoqualmie Pass. Mudslides in

Cowlitz County and flooding in Lewis County closed Interstate 5. Damage throughout the Pacific Northwest estimated at $800 million.

November 1996 – Spokane Area Ice Storm[18, 19]

Federal Disaster #1152. Stafford Act disaster assistance provided – $11.9 million.

Heavy rain, freezing rain and snow fell in Spokane, Pend Oreille, and Klickitat counties.

Up to three inches of ice was deposited on trees, vehicles, buildings, etc., across much of the populated areas of Spokane County. More than 100,000 homes and businesses lost power; some were without power for up to nine weeks. Power outage affected water and sewage pumping systems. Spokane International Airport was closed for two days due to power outage.

Four people died; damage estimated at more than $22 million dollars.

December 1996 - January 1997 – Ice, Wind, Flooding, Snowloading, Landslides[20]

Federal Disaster #1159. Stafford Act disaster assistance provided – $83 million. Small Business Administration loans approved – $31.7 million.

Saturated ground combined with snow, freezing rain, rain, rapid warming and high winds within a five-day period produced flooding and landslides.

Impacted counties – Adams, Asotin, Benton, Chelan, Clallam, Clark, Columbia, Cowlitz, Douglas, Ferry, Franklin, Garfield, Grant, Grays Harbor, Island, Jefferson, King, Kitsap, Kittitas, Klickitat, Lewis, Lincoln, Mason, Okanogan, Pacific, Pend Oreille, Pierce, San Juan, Skagit, Skamania, Snohomish, Spokane, Stevens, Thurston, Walla Walla, Whatcom, and Yakima.

Twenty-four deaths; $140 million (est.) in insured losses; 250,000 people lost power.

More than 130 landslides between Seattle and Everett, primarily along shorelines. Interstate 90 at Snoqualmie Pass was closed due to avalanche.

May 31, 1997 – Tornado Outbreak[21, 22]

A record six tornados touched down in Washington in one day; the state's previous record was four tornados in 1989 for the entire year.

- Four F1 tornados hit Stevens and Spokane counties in northeast Washington.
- Two F0 tornados touched down in western Washington – Vancouver and Tacoma.
- Also, on the same day in Idaho, an F1 tornado struck Athol and an F0 was observed near Lewiston.

In addition, this storm produced severe thunderstorms with large hail up to two to three inches in diameter, heavy rain and flash flooding, and wind gusts to near 80 mph. An F0 tornado has winds of 40-72 miles per hour and is capable of light damage. An F1 tornado has winds of 73-112 mph and is capable of moderate damage.

No deaths or injuries reported.

A record 14 tornados were reported in the state in 1997.

December 14-15 2006 Windstorm. Federal Disaster # 1682.

The most powerful windstorm since the Inauguration Day Storm of 1993 slammed into Washington State with 90 MPH winds on the Coast, gusts up to 70 MPH in the Puget Sound basin, and peak winds well over 100 MPH along the Cascade Crest. Up to 1.5 million residents were without power for up to 11 days. The storm resulted in 15 deaths (including 8 from carbon monoxide poisoning). Governor Gregoire proclaimed an emergency for all 39 Counties. Total damages are still being tallied but will exceed 50 million dollars.

December 1-17 2007 Severe Storm. Federal Disaster # 1734.

During the time period December 1-3, 2007, three storms moved over the Pacific Northwest. December 1st marked the first in the series, producing heavy snow in the mountains and low-land snow throughout western Washington. Snow fall levels ranged from a trace to 1" in Seattle, to many areas away from Puget Sound receiving over 4". On December 2nd, the snow changed over to rain as temperatures increased, accompanied by strong winds. As a low pressure system moved over the Olympic Peninsula, wind gusts of over 80 mph were observed along much of the coast (Hoquiam 81, Destruction Island 93, Tatoosh Island 86) and 40 to 50+ mph inland (Olympia 44, Seattle 48, Bellingham 53).

During this same storm series, a windstorm packing hurricane force winds battered the coasts of Washington and Oregon during December 1-3, 2007. Winds with this storm were second only to that of the 1962 Columbus Day Storm with a recorded gust of 102 mph at Klipsan Beach on the Long Beach Peninsula. Another report of 146 mph was also received from a communication tower at an elevated site (~1500 feet) near radar ridge in Pacific County. These strong winds caused extensive power and communication outages that lasted up to 4 days. The longevity of the strong winds, lasting up to 36 hours made this storm very unique and was responsible for much of the damage. This storm also delivered significant wave heights (top 1/3 of wave heights) of 44 to 48 feet in the offshore waters before unmooring the buoys that were observing them.

The most significant of the three storms arrived December 3rd, with near record high temperatures (59°F for Seattle) and moist tropical air which led to record rainfall and flooding around western Washington. Reports indicate that 6-hour and 24-hour

precipitation amounts were at or near 100-year rain frequency levels. For Sea-Tac Airport, December 3, 2007 became the 2nd wettest day on record with 3.77" (first is 4.93" recorded on October 20, 2003) and the wettest day on record for Bremerton which received 7.50" of rain, breaking the old record of 5.62" set December 10, 1921.

Several sites reached all time record high river flows and set all-time record high flood stage levels, including the Chehalis, which reached nearly 75 ft (10 feet over flood stage), breaking the previous record set in the floods of February 1996. The flooding of the Chehalis River led to widespread flooding throughout western Lewis County, including a stretch of I-5, forcing 20 miles of the interstate to be closed for 4 days. The Coast Guard rescued more than 300 people from the flood areas, and the flooding and mudslides resulted in at least 5 deaths.

A major disaster declaration was issued for 10 counties for Individual Assistance and 12 counties for Public Assistance, comprised of Clallam, Grays Harbor, Jefferson, King, Kitsap, Lewis, Mason, Pacific, Skagit, Snohomish, Thurston and Wahkiakum counties.

Individuals Assistance (IA), SBA low-interest disaster loans and Public Assistance programs were made available to those jurisdictions impacted

As of March 2008, the breakdown of losses follows: [23]

County	HA*	ONA**	SBA***	PA****
Clallam	$219,359	$11,623	$251,400	$277,978
Grays Harbor	$1,556,046	$234,918	$3,867,600	$2,326,407
Jefferson	N/A	N/A	N/A	$201,216
King	$1,370,211	$160,353	$1,594,700	$1,845,386
Kitsap	$1,401,024	$59,419	$1,255,500	$1,195,046
Lewis	$9,583,635	$2,266,483	$19,615,500	$8,034,990
Mason	$1,202,781	$58,506	$1,984,700	$1,997,304
Pacific	$475,217	$49,697	$1,340,100	$231,576
Skagit	N/A	N/A	N/A	$21,050
Snohomish	$494,205	$37,233	$724,700	$1,398,783
Thurston	$726,581	$4,180	$823,400	$1,117,943
Wahkiakum	$128,659	$28,531	$85,800	$160,561
Statewide (PA)	N/A	N/A	N/A	$2,104,756
TOTAL	$17,157,718	$2,910,943	$31,543,400	$20,912,996

TOTAL of all Federal assistance to date: $72,525,057

*HA = Housing Assistance

**ONA = Other Needs Assistance

***SBA = Small Business Administration disaster loans

****PA = Public Assistance for state and local governments, tribes and non-profits (the 75% federal share of completed Project Worksheets)

N/A = These counties were not designated for Individual Assistance

January 6-8, 2009 Severe Winter Storms, Landslides, Mudslides, and Flooding.

Federal Disaster No 1817[24]

A strong, warm and very wet Pacific weather system brought copious amounts of rainfall to Washington during the period 6-8 January, 2009, with subsequent major flooding extending through January 11, 2009, as well as minor flooding that continued through most of January. The storm involved a strong westerly flow aloft with embedded sub-tropical moisture, known as an *atmospheric river* of moisture. Snow levels rose from low levels to between 6,000 and 8,000 feet, with strong westerly winds enhancing precipitation amounts in the mountains. Antecedent conditions from a mid-December through early January region-wide cold snap and associated heavy snow helped set the stage for flooding. This event also produced avalanches in the mountains, and caused more than an estimated 1,500 land/mudslides across the state, and resulted in structural damage to buildings from added snow load, compounded by heavy rains.

All counties of Western Washington lowlands received 3-8 inches of rain, while east of the Cascades, amounts ranged from 2 to 7.5 inches. On January 7, 2009, Olympia set a daily record with 4.82 inches. The National Weather Service issued flood warnings for 49 flood warning points across the state. Some daily rainfall records were broken (but not all-time) on January 7th at airports: Sea-Tac saw 2.29 inches that broke 1.33 inches on January 7th in 1996, Olympia saw 4.82 inches breaking 1.95 set on January 7, 2002, and Quillayute saw 2.88 inches breaking 2.39 set on January 7, 1983 (from NWS).

Emergency Alert System was activated by NWS Seattle and Portland as 22 Western Washington rivers exceeded *major* flood category. Two rivers, the Naselle in Pacific County and the Snoqualmie reached all-time record crests. Six rivers had near-record crests, while Mud Mountain Dam and Howard Hanson Dam had record levels of inflows. The State's primary north-south rail line was also closed. Interstate-5 was closed from milepost 68 to 89 for 43 hours due to water over the roadway around Chehalis. The economic impact of this closure was estimated at $12 million per day.

Public Assistance was provided to 22 counties, while Individual Assistance was provided to 15 counties. As of March 2009, approximately $10 million in federal disaster assistance was paid to Washington residents, with 3,465 homeowners and renters applying for disaster assistance.

Summary of Impacts of Hazardous Weather in Washington State – 1995 to 2008[25]

Year	Fatalities	Injuries	Property Damage	Crop Damage
1995	3	2	$10.3 million	not listed
1996	13	34	$63.9 million	$5.7 million
1997	26	21	$23.6 million	$900,000
1998	4	15	$22.9 million	$85.4 million
1999	6	15	$39.7 million	$300,000
2000	3	21	$11.2 million	$100,000
2001	11	19	$7.6 million	$95.5 million
2002	5	12	$14.5 million	$90.3 million
2003	4	37	$31.3 million	not listed
2004	1	10	$6.4 million	$5.5 million
2005	4	23	$14.5 million	$100.3 million
2006	5	58	$171.7 million	$69.7 million
2007	15	19	$197.28 million	$20,000
2008	7	5	$31.78 million	$105. million
Totals	**107**	**291**	**$646.66 million**	**$558.72 million**

(As of March 25, 2010, 2009 data was not available for inclusion in this edition.)

Jurisdictions Most Vulnerable to Severe Storms

For the State Hazard Mitigation Plan, factors used to determine which counties are most vulnerable to future non-flood, severe storm are:

- Counties most vulnerable to the non-flood meteorological criteria below, as determined by Ted Buehner, Warning Coordination Meteorologist, National Weather Service – Seattle; Tyree Wilde, Warning Coordination Meteorologist, National Weather Service – Portland, OR; Anthony Cavallucci, Warning Coordination Meteorologist, National Weather Service – Spokane; and Dennis Hull, Warning Coordination Meteorologist, National Weather Service – Pendleton, OR.

- How often severe storm events occur, expressed as a percentage of recurrence per year. The percentage used to differentiate jurisdictions most vulnerable differs by storm type and is explained below.

  Data for frequency of severe storm events was obtained from the Special Hazard Events and Losses Database for the United States (SHELDUS, beta version), developed by the Hazard Research Lab at the University of South Carolina, and from the National Climatic Data Center of the National Oceanic and Atmospheric Administration.

SHELDUS uses a variety of NOAA data sources. It covers severe weather events from 1960 through 2000 that caused more than $50,000 in property and/or crop damage. Data obtained from the National Climatic Data Center covered weather events causing more than $100,000 in property and/or crop damage from 1993 through 2003 (except June and July 1993, for which data is not available), with the following exceptions:

- Tornado information is from 1950 to 1992.
- Thunderstorm wind and hail information is from 1955 to 1992.

Analysis of the data sets eliminated duplicate entries between the SHELDUS and National Climatic Date Center data.

The severe storm events for each county's vulnerability are the following:

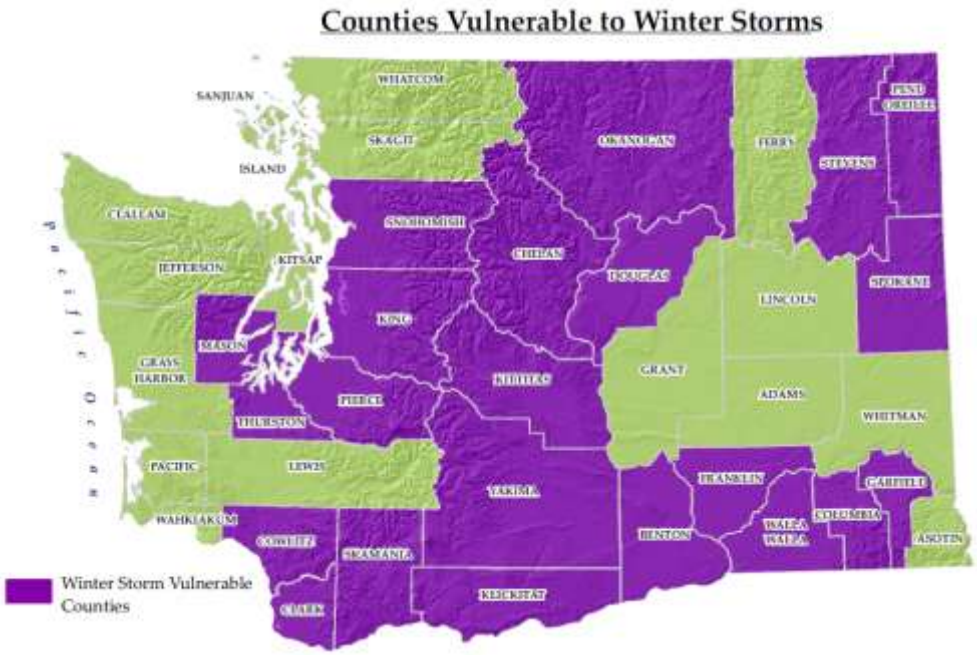
High winds – The National Weather Service defines high winds as sustained winds of 40 mph or gusts of 58 mph or greater, not caused by thunderstorms, expected to last for an hour or more.

Areas most vulnerable to high winds are those affected by a strong pressure difference from deep storms originating over the Pacific Ocean; an outbreak of very cold, Arctic air originating over Canada; or strong air pressure differences between western and eastern Washington that primarily affect the Columbia River Gorge, Cascade Mountain passes, ridges and east slopes, and portions of the Columbia Basin.

Counties considered most vulnerable to high winds are 1) those most affected by conditions that lead to high winds, as described above, **and** 2) those with a high wind recurrence rate of 100 percent, meaning the county experiences at least one damaging high wind event every year. Counties that meet both criteria, or recommended for inclusion by Anthony Cavallucci, Warning Coordination Meteorologist, National Weather Service – Spokane, are highlighted on the map, right, and in Table 1, page 16.

Winter storm – The National Weather Service defines a winter storm as having significant snowfall, ice, and/or freezing rain; the quantity of precipitation varies by elevation. Heavy snowfall is 4 inches or more in a 12-hour period, or 6 inches or more in a 24-hour period in non-mountainous areas; and 12 inches or more in a 12-hour period or 18 inches or more in a 24-hour period in mountainous areas.

Areas most vulnerable to winter storms are those affected by convergence of dry, cold air from the interior of the North American continent, and warm, moist air off the Pacific Ocean. Typically, significant winter storms occur during the transition between cold and warm periods.



Counties considered most vulnerable to winter storm are 1) those most affected by conditions that lead to such storms, as described above, and 2) those with a recurrence rate of 50 percent, meaning the county experiences at least one damaging winter storm event every two years. Counties that meet both criteria, or recommended for inclusion by Anthony Cavallucci, Warning Coordination Meteorologist, National Weather Service – Spokane, are highlighted on the map, above, and in Table 1, page 17.

Table 1. Counties Most Vulnerable to High Winds (shade indicates most vulnerable)

	Vulnerable to Meteorological Conditions	Recurrence Rate (>100% – At least 1 occurrence per year)
Adams	YES	70%
Asotin	NO	70%
Benton	YES	140%
Chelan	YES, East Slopes of Cascades	Included on recommendation of National Weather Service
Clallam	YES, Pacific Coast	118%
Clark	YES	130%
Columbia	YES	120%
Cowlitz	YES	113%
Douglas	NO	80%
Ferry	YES, Higher Elevations	65%
Franklin	NO	80%
Garfield	YES	70%
Grant	YES	93%
Grays Harbor	YES	170%
Island	YES	148%
Jefferson	YES, Pacific Coast	125%
King	YES	133%
Kitsap	YES	125%
Kittitas	YES	110%
Klickitat	YES	73%
Lewis	YES	123%
Lincoln	YES	75%
Mason	YES	165%
Okanogan	YES	83%
Pacific	YES, Pacific Coast	213%
Pend Oreille	YES	73%
Pierce	YES	165%
San Juan	YES, Western Half	173%
Skagit	YES	188%
Skamania	YES	95%
Snohomish	YES, Western Half	175%
Spokane	YES	105%
Stevens	YES, Higher Elevations	83%
Thurston	YES	175%
Wahkiakum	YES	118%
Walla Walla	YES	90%
Whatcom	YES, Western Half	190%
Whitman	YES	93%
Yakima	YES	103%

Table 2. Counties Most Vulnerable to Winter Storm (shade indicates most vulnerable)

	Vulnerable to Meteorological Conditions	Recurrence Chance / Year (>50% – At least one occurrence every two years)
Adams	NO	35%
Asotin	YES	23%
Benton	NO	48%
Chelan	YES	Included on recommendation of National Weather Srvs.
Clallam	YES	48%
Clark	YES, East County	85%
Columbia	YES	38%
Cowlitz	YES	60%
Douglas	YES	143%
Ferry	YES	23%
Franklin	NO	33%
Garfield	YES	73%
Grant	NO	60%
Grays Harbor	NO	40%
Island	NO	43%
Jefferson	YES	43%
King	YES	70%
Kitsap	YES	35%
Kittitas	YES	110%
Klickitat	YES	38%
Lewis	YES	33%
Lincoln	YES	25%
Mason	YES	60%
Okanogan	YES	128%
Pacific	NO	33%
Pend Oreille	YES	Included on recommendation of National Weather Srvs.
Pierce	YES	60%
San Juan	YES	48%
Skagit	YES	58%
Skamania	YES	88%
Snohomish	YES	58%
Spokane	YES	55%
Stevens	YES	Included on recommendation of National Weather Srvs.
Thurston	YES	50%
Wahkiakum	NO	35%
Walla Walla	YES	98%
Whatcom	YES	65%
Whitman	YES	30%
Yakima	YES	73%

What's New:

StormReady Program:

Community leaders can help ensure their community is ready for hazardous weather with the National Weather Service's StormReady program. StormReady, a program started in 1999 in Tulsa, OK, helps arm America's communities with the communication and safety skills needed to help save lives and property–before and during the event. StormReady helps community leaders and emergency managers strengthen local safety programs.

As of April 2010, Washington State had 47 StormReady designations, which included 25 community designations, 11 county designations, 4 TsunamiReady communities, 4 TsunamiReady counties, 1 TsunamiReady Indian Nation, 1 commercial site and 1 StormReady supporter.

A companion to StormReady is the TsunamiReady program that helps coastal communities better prepare for tsunamis. StormReady and Tsunami Ready communities are better prepared to save lives from the onslaught of severe weather through advanced planning, education and awareness. No community is storm proof, but StormReady can help communities save lives.

Skywarn Weather Spotters:

Skywarn (TM) Weather Spotters are a National Weather Service (NWS) team of volunteers, trained to observe and report significant weather. Weather spotters support their local community and emergency managers by providing the NWS with timely and accurate severe weather reports on an event-driven basis. These reports are an integral part of the NWS mission to help saves lives and property through flood and weather watches, warnings, and advisories.

Accurate and reliable weather information from the general public is often difficult to obtain. The NWS has found that trained weather spotters greatly improve information quality. The NWS works with other volunteer organizations in the Skywarn (TM) Weather Spotter program, such as Amateur Radio, the American Red Cross, and local emergency managers.

The NWS conducts training for weather spotters upon request from local emergency managers or other volunteer organizations. The training consists of how the program works, and ways to recognize and report significant hazardous weather. The Skywarn Weather Spotter program supports StormReady Community applications, both initial and renewal applications.

Skywarn (TM) Weather Spotter reports provide "ground truth" for NWS technologies, such as Doppler weather radar and satellite imagery. These reports, when integrated with all available weather information sources, help forecasters detect hazardous

weather. Spotter reports also reinforce NWS warning messages. The NWS, media, and emergency managers use these reports, encouraging people to take proper action and get themselves, their family, their pets and livestock, and/or their employees and clients, out of harm's way.

CoCoRaHS:

On June 1, 2008 The Evergreen State became the 32nd state to join the nationwide Community Collaborative Rain Hail and Snow or CoCoRaHS community.

What exactly is CoCoRaHS?
It is a unique, non-profit, community-based network of volunteers of all ages and backgrounds, working together to measure and map precipitation (rain, hail and snow). By using low-cost measurement tools, stressing training and education, and utilizing an interactive web site (www.cocorahs.org), the aim is to provide the highest quality data for natural resource, education and research applications.

Why is CoCoRaHS important?
As most Washington residents know, precipitation varies greatly with location, topography, storm type and season. The same can be said of snow and hail, and the amount of precipitation that falls, of any type, can vary greatly over short distances. Meteorologists, emergency managers, engineers, hydrologists, insurance experts, the media, and many others, are very interested in precipitation data particularly during more extreme events that can result in flooding and landslides, as well as large hail and heavy snow amounts. Participation in the CoCoRaHs program allows these groups of people to see, measure and study the variability of precipitation across Washington!

NWSChat:

NWSChat is an Instant Messaging program utilized by National Weather Service (NWS) operational personnel to share critical warning decision expertise and other types of significant weather information essential to the NWS's mission of saving lives and property.

This information is exchanged in real-time with the media and emergency response community, who in turn play a key role in communicating the NWS's hazardous weather messages to the public.

NWSChat also provides media and emergency response partners with the ability to communicate significant event reports back to NWS operational personnel, who in turn utilize the information to make effective warning decisions.

NWS partners can use NWSChat as an efficient means of seeking clarifications and enhancements to the communication stream originating from the NWS during a fast-paced significant weather or hydrologic event.

The emergency management community can easily register for NWSChat by visiting https://nwschat.weather.gov/ Use the Request NWSChat Account – NWS Partners link. As a part of the registration process, indicate which affiliation your belong with such as Local Emergency Manager and Amateur Radio.

NWSChat also uses Pidgin as the Instant Messaging software. You can easily download Pidgin, following your local IT guidelines. Pidgin also permits receipt of 'bot' messages – hyperlinks to NWS warning messages that arrive seconds after transmission, a big plus with this program. Refer to https://nwschat.weather.gov/ for more details. Your local NWS forecast office Warning Coordination Meteorologist is another resource for additional questions.

E-Warn:

E-Warn is a National Weather Service (NWS) warning message dissemination program that delivers within seconds of transmission, NWS warning messages to your designated email address. The email address can be for a typical email account to a PC or laptop, as well as to hand-held devices of choice.

The only other requirements are self-selected target county or counties, as well as what types of desired warning messages such as flood, high wind, snow or tornado.

Registration and more information about E-Warn is available from your local NWS forecast office Warning Coordination Meteorologist.

National Weather Service (NWS) Web Sites:

Four NWS forecast offices serve Washington, from Seattle, Spokane, Pendleton and Portland. Their web sites offer a wealth of information that support the four phases of emergency management - mitigation, preparedness, response, and recovery.

Key web site elements include the Area Forecast Discussion, latest outlooks, watches, warnings and advisories, climatic/historical data resources, the Advance Hydrologic Predictive Service or AHPS, and digital forecasts including GIS mapping forecast fields.

The Area Forecast Discussion (AFD) is composed by the forecasters on duty four times per day near 3 AM and PM as well as 9 AM and PM. The discussions provide additional insight to the latest forecasts and warning messages, including timing, uncertainty and confidence. The AFD is a useful tool in the emergency management decision making process.

AHPS provides the latest river and stream forecasts and during expected or occurring higher flows, warning messages. The river forecast charts show the stream flow from the past 72 hours and the latest guidance from the River Forecast Center for the following 72 hours. For the latest flood forecast information, refer to the local forecast office flood messages.

Digital forecasts from the forecast offices are updated as often as each hour. They can be viewed either as images or graphics for each forecast field (such as temperature and wind), as well as the forecast grids themselves that can be used as GIS layers. For complete information about obtaining the forecast grids for use as GIS layers, visit http://www.weather.gov/ndfd/technical.htm

The NWS web sites offer so much more information such as Doppler weather radar loops, satellite image loops, current observations on land and at sea, educational and safety information, weather records, local storm or weather spotter reports, and more.

[1] Notes from and personal communication with Ted Buehner, Warning Coordination Meteorologist, National Weather Service, Seattle Forecast Office, April 2, 2003.

[2] *Climate of Washington*, Western Regional Climate Center, Desert Research Institute, http://www.wrcc.dri.edu/narratives/WASHINGTON.htm, (February 20, 2003).

[3] Notes from Ted Buehner, Warning Coordination Meteorologist, National Weather Service, Seattle Forecast Office, April 2, 2003.

[4] Chris Hill et al., *Top Ten 20th Century Weather Events In Washington State*, National Weather Service, Seattle Forecast Office, December 1999, http://www.wrh.noaa.gov/pqr/paststorms/washington10.php (25 March 2010).

[5] Ibid.

[6] Ibid.

[7] Ibid.

[8] Eric Sorensen, *Columbus Day 1962, Memories of Storm That Roared Still Vivid*, Seattle Times, October 6, 2002.

[9] Ibid.

[10] Fujita Tornado Measurement Scale, *Understanding Your Risks: Identifying Hazards and Estimating Losses*, Federal Emergency Management Agency, FEMA 386-2, August 2001.

[11] Information from *Flood Mitigation Implementation Measures Report for Whatcom County, FEMA-676-DR*, Washington State Department of Emergency Services et al., November 1983.

[12] Chris Hill et al., *Top Ten 20th Century Weather Events In Washington State*, National Weather Service, Seattle Forecast Office, December 1999, http://www.wrh.noaa.gov/pqr/paststorms/washington10.php (25 March 2010).

[13] Unless otherwise noted, disaster assistance costs come from spreadsheet maintained by State Hazard Mitigation Officer for assistance programs managed by Washington Military Department, Emergency Management Division, (February 20, 2003). Typically, total disaster costs are about twice the total shown.

[14] Chris Hill et al., *Top Ten 20th Century Weather Events In Washington State*, National Weather Service, Seattle Forecast Office, December 1999, http://www.wrh.noaa.gov/pqr/paststorms/washington10.php (25 March 2010).

[15] Information from *Inauguration Day Wind Storm January 20, 1993 After-Action Report*, Washington State Department of Community Development, August 1993.

[16] Chris Hill et al., *Top Ten 20th Century Weather Events In Washington State*, National Weather Service, Seattle Forecast Office, December 1999, http://www.wrh.noaa.gov/pqr/paststorms/washington10.php (25 March 2010).

[17] Information from *Interagency Hazard Mitigation Team Report, with Early Implementation Strategies for DR-1079-WA and DR-1100-WA*, Federal Emergency Management Agency Region X, July 1996.

[18] Chris Hill et al., *Top Ten 20th Century Weather Events In Washington State*, National Weather Service, Seattle Forecast Office, December 1999, http://www.wrh.noaa.gov/pqr/paststorms/washington10.php (25 March 2010).

[19] Information from *Hazard Mitigation Survey Team Report for the 1996-1997 Washington Winter Storms*, Washington State Emergency Management Division and the Federal Emergency Management Agency Region 10, 1997.

[20] Ibid.

[21] Chris Hill et al., *Top Ten 20th Century Weather Events In Washington State*, National Weather Service, Seattle Forecast Office, December 1999, http://www.wrh.noaa.gov/pqr/paststorms/washington10.php (25 March 2010).

[22] Fujita Tornado Measurement Scale, *Understanding Your Risks: Identifying Hazards and Estimating Losses*, Federal Emergency Management Agency, FEMA 386-2, August 2001.

[23] FEMA. *Washington Disaster Aid Tops $72.5 Million* . (2008). Accessed March 23, 2009. Available at: http://www.fema.gov/news/newsrelease.fema?id=42969

[24] FEMA. Almost $11 Million in Disaster Assistance to Washington Residents with March 31st Deadline Fast Approaching. March 20, 2009. Accessed March 23, 2009. Available at: http://www.fema.gov/news/newsrelease.fema?id=47770

[25] Summary tables of hazardous weather fatalities, injuries, and damage costs listed by state, for years 1995 through 2008, National Oceanic and Atmospheric Administration, National Weather Service, Office of Climate, Water and Weather Services, <http://www.weather.gov/os/hazstats.shtml>, (25 March 2010).